WHEN A ROSE IS A ROSE IN SPEECH BUT A TULIP IN WRITING

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Abstract

We report the pattern of performance on language tasks by a neurologically impaired patient, RCM, who makes semantic errors in writing to dictation and in written naming, but makes very few errors at all (and no semantic errors) in spoken naming, oral reading, or spontaneous speech. RCM also shows a significant effect of concreteness on spelling accuracy and other features of so-called "deep dysgraphia." However, it is shown that, unlike previously reported patients described as deep dysgraphic, RCM has intact semantic processing but impairment in accessing lexical-orthographic representations, at least for the items tested. These results demonstrate that the collection of features labelled as "deep dysgraphia" can arise from damage to different cognitive processes. Detailed analyses of RCM's performance across lexical tasks, at two different time periods of recovery, provide evidence that lexical orthographic representations can be either directly activated by lexical semantic representations, or activated by the interaction of lexical semantic and sublexical information from phonology-to-orthography conversion mechanisms.

Key words: aphasia, agraphia

Introduction

It is now well established that the production of semantic errors in naming (such as producing "cat" in response to a picture of a dog) can have multiple causes. First, semantic errors in naming can result from damage to the semantic system. In such cases, semantic errors should be produced in all tasks involving the semantic component, irrespective of stimulus type and of input or output modality. The performance of patients who produce comparable patterns of semantic errors in written and oral naming, word/picture matching, oral reading, and spelling to dictation is most plausibly accounted for by proposing damage at the level of the lexical-semantic system (e.g., Butterworth, Howard and Mcloughlin, 1984; Howard and Orchard-Lisle, 1984; Hillis, Rapp, Romani et al., 1990). However, semantic errors can also arise from damage to processes other than the semantic system. The existence of patients who make semantic errors in naming pictures but not in naming from tactile or auditory input demonstrates that semantic paraphasias can also arise from impaired visual recognition processes or impaired access to semantic information from vision (Beauvois, 1982; Chanoine, Teixeira Ferreira, Demonet et al., 1997; Coslett and Saffran, 1992; Hillis and Caramazza, 1995; Iorio, Falanga, Fragassi et al., 1992; Lhermitte and Beauvois, 1973). Furthermore, cases in which semantic errors are observed primarily or exclusively in spoken output with

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relatively preserved writing (Hier and Mohr, 1977; Assal, Buttet and Jovilet, 1981; Ellis, Miller and Sin, 1983; Caramazza and Hillis, 1990; Shelton and Weinrich, 1997) provide evidence that semantic errors can also occur as a consequence of impaired access to lexical phonological representations (damage to the phonological output lexicon). The semantic errors of these patients cannot be ascribed to a semantic impairment, because they are able to: (a) write the name of pictures that elicit semantic errors in oral naming; and (b) clearly define printed words that elicit semantic errors in oral reading (Caramazza and Hillis, 1990). A few cases of semantic errors in written output with relatively preserved spoken output have also been reported (Bub and Kertesz 1982a; Hillis and Caramazza, 1995a)[1], indicating that semantic errors might also arise from impairment at the level of access to lexical orthographic representations (the orthographic output lexicon).

It is also well established that semantic errors in oral reading and in writing-to-dictation do not seem to occur when the only impairment involves the lexical system – that is, damage to either the semantic component or the output lexicons. All reported cases of semantic errors in reading and writing-to-dictation have had concomitant damage to sublexical mechanisms for converting phonology to orthography or orthography to phonology. It has been argued that the co-occurrence of damage to lexical processes and to sublexical conversion mechanisms is necessary for the production of semantic errors in output because intact sublexical (orthography-to-phonology or phonology-to-orthography) mechanisms would otherwise "block" the production of semantic errors (Hillis and Caramazza, 1991; Nickels, 1992; see also papers in Coltheart, Patterson and Marshall, 1980). One proposal of how lexical and sublexical processes interact in preventing semantic errors in cases of damage to the semantic system is the "summation hypothesis" (Hillis and Caramazza, 1991, 1995b; Miceli, Capasso and Caramazza, 1994; see Newcombe and Marshall, 1980; Morton and Patterson, 1980; Patterson and Hodges, 1992, for similar proposals). This hypothesis specifies that lexical forms for output are activated not only by the semantic system but also by input from sublexical conversion processes. As a consequence, at least partial sparing of both systems would lead to activation of the correct lexical form or a phonologically/orthographically related form instead of purely semantically related forms. Direct evidence for this hypothesis of "summation" of activation from semantic and sublexical mechanisms for spoken output comes from patients who show improved oral naming of pictures when partial phonological information is provided, and improved naming of pseudowords (e.g., lepperd) when partial semantic information (e.g., "animal") is provided (Hillis and Caramazza, 1995b)[2]. Indirect evidence for the interaction of sublexical and semantic mechanisms in

[1]Roeltgen, Rothi and Heilman, 1986; Patterson and Shewell, 1987; and Assal, Buttet and Jolivet, 1981, also reported patients who made semantic paragraphias, but their patients also made semantic errors in speech (or had very poor spoken output). They also had impaired or unreported comprehension of words that elicited semantic paragraphias. Rapp, Benzing and Caramazza (1997) reported a patient, PW, who made semantic errors in both spoken and written naming, but on different items. PW's comprehension of spoken and written words was intact, indicating that his errors arose after activating an intact semantic representation.

[2]There may also be a mechanism for directly activating lexical phonological representations from lexical orthographic representations, since some patients can read even exception (irregular) words well, although they do not comprehend them (Cipolotti and Warrington, 1995; Lambon Ralph, Ellis et al., 1995; Raymer and Berndt, 1996; Greenwald and Berndt, 1998).

selecting orthographic representations for written output has also been reported. That is, semantic errors in writing that are due to damage at the level of the orthographic output lexicon resolve when phonology-to-orthography conversion mechanisms improve (JC, reported by Bub and Kertecz, 1982a, 1982b; SJD, Hillis and Caramazza, 1995a). In the case of SJD, improvement was brought about by explicitly retraining phonology-to-orthography conversion. One indication that her improvement was due to increased use of these procedures, rather than general improvement at the level of the orthographic output lexicon alone, was that she continued to make errors that were both phonologically and semantically related to the target, even though she stopped making purely semantic errors.

In this paper we report performance of a patient, RCM, who makes semantic errors in writing, but not in speech production or in comprehension tasks, following a left frontal stroke. Her pattern of performance across lexical tasks is consistent with the proposal that her errors arise from damage at the level of the orthographic output lexicon and damage to phonology-to-orthography conversion mechanisms. Her semantic errors in written output are accounted for by proposing that an intact semantic representation activates a number of semantically related orthographic representations in the output lexicon, and that the one with the highest degree of activation (or lowest threshold) is selected for further processing. We also report that as RCM's ability to use phonology-to-orthography conversion processes improved, there was a marked reduction in the production of semantic errors and a corresponding increase in the production of phonologically/orthographically similar word errors. This finding is consistent with the hypothesis that she increasingly relied on input from partially functioning phonology-to-orthography conversion procedures in the selection of lexical orthographic forms. The implications of RCM's performance for models of normal lexical access and for claims about the nature of "deep dysgraphia" are considered.

Case Report

At the time of testing, RCM was an 82 year old, right-handed woman with a history of hypertension and diabetes who presented to the hospital when she noticed a sudden inability to write while attempting to write checks to pay her monthly bills. She also complained of mild difficulty thinking of words in conversation. A neurological examination at presentation was entirely normal except for her language difficulty. Her spontaneous speech was fluent and grammatical with rare hesitations for word finding. Comprehension of words and complex commands was spared with both spoken and written stimuli. Repetition of words and of high and low probability sentences was also intact. Visual confrontation naming was 100% accurate, but word fluency was impaired (e.g., she named only 4 animals in 60 seconds). Her oral reading, writing, and naming performance are reported in detail below. A speech-language pathology evaluation, which included the Western Aphasia Battery and non-standardized tests, yielded an impression of mild anomic aphasia and deep dysgraphia. She also had difficulty reading pseudowords, such as *hannee*. A head CT scan 6 days post-onset showed a subacute infarct in the left frontal cortex, including the operculum. A brain MRI one month later showed the left frontal infarct with a small amount of hemorrhagic conversion (Figure 1).

RCM's past medical history is notable only for chronic hypertension and type II diabetes mellitus. She never smoked or drank alcohol. RCM lived alone, and was taking care of herself at the time of her stroke. She was tested during two time periods. Study 1 was carried out in the first week after her stroke (12/2/96-12/6/96) while she was still

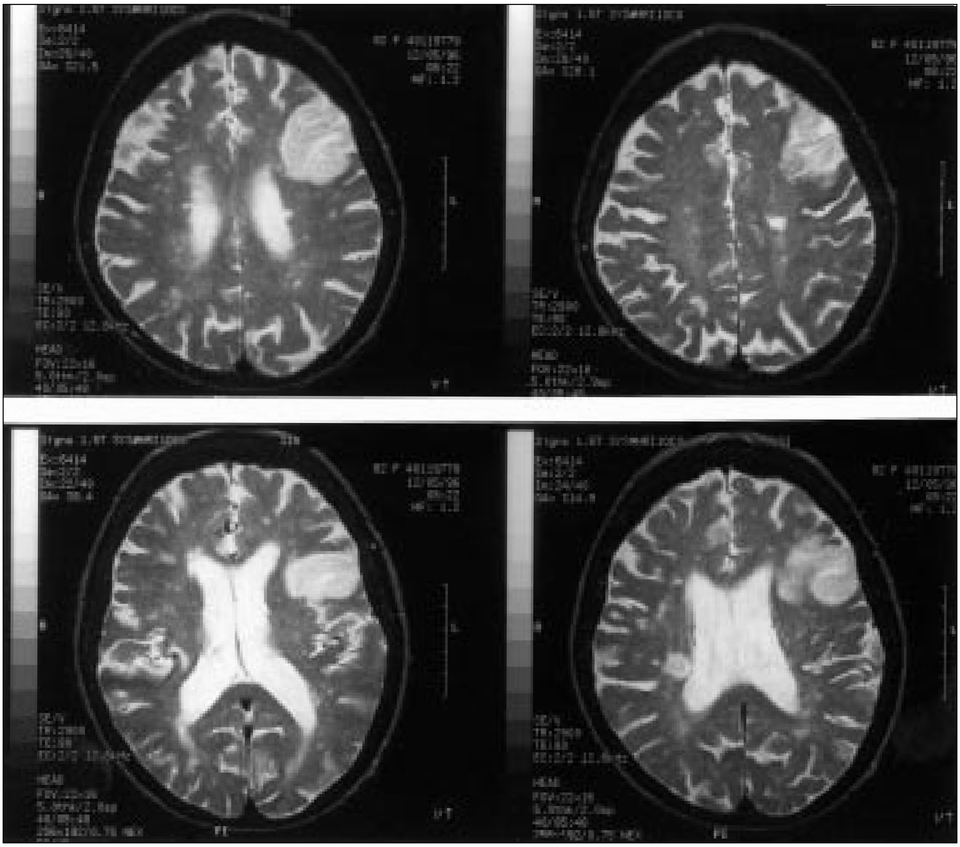

Fig. 1 – *Brain MRI showing RCM's left frontal infarct.*

hospitalized, and Study 2 was carried out two weeks later (12/26/96 to 1/3/97) after returning to her home. She was tested daily in the hospital, and thrice weekly as an outpatient.

STUDY 1

Materials and Methods

In Study 1, RCM was administered a battery of lexical processing tasks. For oral and written naming, a set of 34 pictures was presented. One half (17) of the stimuli were presented for each output modality in each session, using an ABBA design for presentation. To evaluate comprehension, separate sets of 34 object names were presented for a written word/picture verification task and a spoken word/picture verification task. For these tasks, each name was presented 3 times, once with the correct picture (a picture of a bus with the word *bus*), once with a semantic foil (a picture of a train with the word *bus*), and once with a picture of an object with a phonologically similar name (a picture of a bud with the word *bus*). She was asked to verify or reject correspondence between the picture and the object name. She was also administered a list of 34 (17 concrete, 17 abstract) words and 25 nonwords for spelling-to-dictation, and a separate list of 34 (17 concrete, 17 abstract) words and 25 nonwords for oral reading. She was asked to repeat each stimulus (word or nonword) before writing it. The pseudowords were constructed by changing one letter of a real word

(e.g., clock → slock), and were matched in length in letters and phonemes to the words. The word stimuli for each task were matched for word frequency, word class, length in number of phonemes, and length in number of letters. In addition, the set of 34 pictures (from Snodgrass and Vanderwart, 1980) were matched to the 17 concrete words in each word list for familiarity (Snodgrass and Vanderwart, 1980), as well as word frequency and number of syllables.

Performance was scored in terms of accuracy (for words) and plausibility of phonology-to-orthography correspondence (for words and pseudowords). An error was scored as phonologically plausible if the graphemes selected for the phonemes in the stimulus were ones that correspond to those phonemes in at least one word in English. There was 100% agreement between two independent scorers (the first 2 authors) in identifying the phonologically plausible errors in response to words, using these criteria.

Results

The results of Study 1 testing are summarized in Table I. RCM's performance in spoken production tasks was generally very good. Her oral naming was accurate for 34/34 (100%) of the pictures, and her oral reading was accurate for 33/34 (97%) of the words and 17/25 (68%) of the pseudowords presented. Her one error in reading a word and her errors on nonwords consisted solely of visually similar real words (e.g., *slock* → "block"; *ruv* → "row"). Furthermore, repetition of words and nonwords was without error. RCM's single word comprehension was also excellent, as indicated by her flawless performance in word/picture verification in both spoken and written modalities.

TABLE I

RCM's Error Rates (#Errors/Total × 100) and Types in Selected Tasks in Study 1

Task	Correct/ total	Percent correct	Predominant error type
Oral picture naming	34/34	100%	
Written picture naming	18/34	53%	Semantic errors
Writing to dictation: words	16/34	47%	Semantic errors, orthographically similar words, nonwords
Writing to dictation: nonwords	0/25	0%	Orthographically similar words or unrelated
Oral reading: words	33/34	97%	Orthographically similar words
Oral reading: nonwords	17/25	68%	Orthographically similar words
Repetition: words	34/34	100%	
Repetition: nonwords	25/25	100%	
Spoken word/picture verification	34/34	100%	
Written word/picture verification	34/34	100%	

In contrast to her good performance in spoken production and both written and spoken comprehension, RCM's written production was markedly impaired. Table II shows the distribution of her errors in written production. RCM made 16/34 errors (47%) in writing the names of the pictures. Her 16 errors in written naming were predominantly (13/16; or 81%) semantic errors, such as eagle → *owl*, bus → *airplane*[3]. Her remaining errors were: one unrelated word or visual

[3]Throughout this paper, written word stimuli or responses are given in italics, and spoken word stimuli or responses are given in quotation marks. The stimulus precedes the arrow, and the response follows the arrow.

TABLE II

Distribution of Errors in Spelling for RCM at the Time of Study 1

	Error distribution					
	Error rate	Semantic	Sem + orth/phon	Orth/phon	Nonwords	Other
Writing to dictation Abstract + Concrete:	53% 18/34	33% 6/18	0%	33% 6/18	33% 6/18	0%
Written picture naming Object Pictures:	47% 16/35	81% 13/16	6% 1/16	0%	6% 1/16	6% 1/16
Total	49% 34/69	56% 19/34	3% 1/34	18% 6/34	21% 7/34	3% 1/34

error (barn → *lunch box*), one semantically and orthographically/phonologically related word (watch → watchful), and one nonword (zebra → *jephrys*). RCM often spontaneously produced the pictures' spoken names simultaneously with her written responses. All of her spontaneously produced oral names were correct, even when accompanied by an incorrect written name (with the exception of "lunch box" which was produced both orally and in writing in response to a picture of a barn). RCM incorrectly spelled to dictation 7/17 (41%) of the concrete words and 11/17 (65%) of the abstract words. Her errors included semantically related responses (e.g., "kind" → *nice*), orthographically similar words (e.g., "turtle" → *tumult*), and nonword misspellings (e.g., "paradox" → *perxodenin*), in equal proportions.

RCM was unable to spell any pseudowords correctly. Many of her errors on pseudowords bore no resemblance to the target (e.g, "besk" → *to*), but others were orthographically or phonologically related words (e.g., "pon" → *powder;* "teef"→ *beef*)[4]. When we score pseudoword spelling according the accuracy of individual phonological segments (rather than the accuracy of the whole stimulus string) we find that RCM accurately spelled only 42% of the phonological segments.

In summary, at the time of Study 1 RCM had marked difficulty in written spelling of both words and nonwords. Her predominant errors on words were semantic paragraphias, while predominant errors on nonwords were unrelated or phonologically similar words. This set of results indicates damage to both lexical and sublexical spelling processes.

STUDY 2

Materials and Methods

In Study 2, RCM was administered the Johns Hopkins University Dysgraphia Battery and Dyslexia Battery (Goodman and Caramazza, 1986). The Dysgraphia Battery includes spelling-to-dictation of 326 words and 34 pseudowords, written naming of 51 pictures, and

[4]Each phoneme in the stimulus word was counted as a "phonologic segment". If RCM produced a letter or letters corresponding to that phoneme in approximately the same serial position as the phoneme within the word, that phonologic segment was scored as correct. Insertions were scored as one-half point off the phonologic segments before and after the insertion. Additions at the end of the word were scored as an incorrect final phonologic segment. So, the stimulus "pon" (/pan/) spelled as *powder* was scored as 2/3 correct phonologic segments. The error "pon" → *ponder* would also have been scored as 2/3 correct segments.

oral spelling-to-dictation of 120 words and 20 pseudowords. RCM was also asked to write the names and then say the names of 30 pictured verbs and 30 pictured nouns matched to the base frequency of the verbs, and 30 pictured nouns matched to the cumulative frequency of the verbs (Zingeser and Berndt, 1990). In addition, she was given a task to evaluate the effect of grammatical word class in spelling homonyms. She was presented with written sentences with blanks for the target words, and was dictated the full sentence including the word to be written in the blank. For instance, she was presented with the spoken stimulus, "I will post the sign; write the word post" and with the written stimulus: *I will ____ the sign*, along with the instruction, "Write the word post". Each homonym was used once as a noun (e.g., The car hit the post) and once as a verb (I will post the sign). On a separate day she read aloud the homonym pairs in their appropriate grammatical contexts.

Results

As was the case at the time of Study 1, RCM's spoken production performance at the time of Study 2 continued to be within normal limits. She made only 3 (3%) errors in her oral naming of the 90 pictures corresponding to nouns and verbs. Two of these responses were, in fact, probably acceptable responses. A picture of a ghost was named as "goblin" in oral naming (but *halloween* in written naming). A picture of a girl's skirt being ripped on a fence, to depict the verb "rip", elicited the oral name "snagged" (but the written name *torning*). Additionally, in the homonym task RCM correctly read all of the sentences containing homonyms.

RCM's written production continued to be impaired at the time of Study 2. On the test of written picture naming of nouns and verbs, RCM made 34 errors in response to 90 pictures, of which 15 (44%) were semantic errors and 2 (6%) were orthographically similar words (e.g., broom → *brown*). She also made four semantically and orthographically/phonologically similar errors (shaving → *shedding*). Her remaining errors (38%) were nonword misspellings (e.g., wagon → *wagoor*). There were no statistically significant differences in her spelling of nouns vs. verbs either in terms of overall written naming accuracy or in the rate of semantic errors.

In the written picture naming section of the Dysgraphia Battery, RCM made errors on 31% (16/51) of the pictures. Her errors consisted of: 38% nonword misspellings (e.g., fish → *firsh*); 38% semantically and orthographically similar words (e.g., thumb → *thimble*; skirt → *shirt*) including 2 morphological errors (e.g., shoe → *shoes*); 13% orthographically similar words (e.g., watch → *west),* and 13% semantic errors (e.g., shirt → *jacket*). Interestingly, one of her nonword misspellings appeared to be misspelling of a semantically related word (e.g., tiger → (stripe?) → *stirke*).

On the task that required writing homonyms to dictation, RCM made errors in writing 7/33 of the homonyms when used as verbs and 4/33 of the same homonyms when used as nouns. Only one of her 11 errors was a semantic paragraphia ("post" → *read* in the sentence, *I will post the sign*). All of her remaining errors were orthographically similar words (e.g, "bowl" → *boat* in the sentence, *Eat a bowl of soup*), of which half (5/10) were morphological errors (e.g., "pet" → *pets*, in the sentence, *Don't pet the animals.*). RCM made an error on *both* the noun and the verb form of a homonym for only one item: "I will fire the worker; write fire" elicited the written response, *I will fixed the worker*; "Put a log on the fire; write fire" elicited the response, *Put a log on the file*.

In spelling to dictation the words from JHU Dysgraphia Battery, RCM made errors on 42% (136/326). The distribution of her error types is shown in Table III. With word stimuli, she no longer made errors that were purely semantic in nature (with the possible exception of "strict" → *listens*). However, erroneous responses that were both semantically and orthographically related to the target were now common (42/136; 30%), of which 30 were "morphologically" related to the target (see Table IV for examples). The remainder of her errors were: nonword misspellings (44%) and orthographically similar words (24%). Her error rate was lower for concrete words (3/21; 14.2%) relative to abstract words (11/21; 52.3%) on lists of nouns matched for frequency and word length (χ^2 = 6.86; d.f. = 1; p < .01). In addition, her error rate was significantly lower for high frequency words (52/146; 35.6%) versus low frequency words (69/146; 47.3%; χ^2 = 4.08; d.f. = 1; p < .05). There were no significant effects of word

TABLE III

Distribution of Errors in Spelling for RCM at the Time of Study 2

	Error distribution					
	Error rate	Semantic	Sem + orth/phon	Orth/phon	Nonwords	Other
Writing to dictation						
Dysgraphia Battery:	42% 136/326	1% 1/136	31% 42/136	23% 31/136	44% 60/136	1% 2/136
Homonyms:	17% 11/66	9% 1/11	0%	91% 10/11	0%	0%
Written picture naming						
Noun/Verb Pictures:	38% 34/90	44% 15/34	12% 4/34	6% 2/34	38% 13/34	0%
Object Pictures:	31% 16/51	13% 2/16	38% 6/16	13% 2/16	38% 6/16	
Total	37% 197/533	10% 19/197	26% 52/197	23% 45/197	40% 79/197	1% 2/197

TABLE IV

Examples of RCM's Errors on Words in Spelling to Dictation in Study 2 (Errors on the Johns Hopkins Dysgraphia Battery)

Stimulus	Response	Stimuls	Response
Orthographically/ Phonologically similar words		Morphologically related words	
offense	*often*	happy	*happiness*
cloak	*clock*	drive	*driving*
career	*caress*	learn	*learned*
sleek	*slicker*	music	*musical*
jerk	*junk*	caught	*catch*
chant	*chance*	bright	*brightness*
myth	*method*	faith	*faithful*
hurry	*happy*	skip	*skipped*
happen	*happy*	baby	*babies*
Nonword misspellings		Pseudo-morphological errors	
deny	*denite*	shall	*shallen*
loud	*loughes*	space	*spaceful*
broad	*braden*	speak	*speeching*
could	*kowden*	belief	*believen*
vivid	*vidivier*		
strange	*instrance*		
rather	*rabber*		
ledge	*leadge*		

length, grammatical word class (χ^2 = 1.78; d.f. = 1, n.s.), or probability of correct spelling by applying the most common phonology-to-orthography conversion rules (i.e., regularity; χ^2 = 0.574; d.f. = 1; n.s.).

At the time of Study 2, RCM continued to have difficulty with pseudoword spelling. These stimuli resulted in an error rate of 97% (33/34); that is, she spelled only one of the pseudowords completely correctly. However, when pseudowords are scored in terms of the accuracy of segments we find that 67% of segments were spelled correctly. This represents a striking improvement over her pseudoword spelling accuracy at the time of Study 1 (from 42% or 42/100, to 67% or 117/175 correct segments; χ^2 = 16.1; d.f. = 1; $p < .0001$). In fact, as can be seen in Table V, at the time of Study 2 her responses to pseudowords were often quite close to the target. Furthermore, whereas at the time of Study 1 RCM's responses to pseudoword stimuli were largely phonologically similar word responses (92%), at the time of Study 2 there were only 18% phonologically similar word responses to pseudowords. The remaining errors were phonologically similar nonword responses. These results suggest that at Time 1 RCM rarely even engaged the sublexical spelling procedures in attempting to spell pseudowords; rather, she simply spelled a similar sounding word. In contrast, at Time 2 the sublexical system was fairly consistently engaged in the spelling of pseudowords, although it was not yet entirely successful. Other evidence indicating the partial recovery of the sublexical system at the time of Study 2 is the fact that in Study 2 RCM's nonword errors to *word* stimuli included eight phonologically plausible errors (e.g., "leopard" → *lepord;* ledge → *leadge;* weave → *weve*; fence → *fense*). These are responses that, presumably, would have been generated by a sublexical spelling procedure. There were no such responses at the time of Study 1.

Finally, it is also worth noting, there were no differences between oral and written spelling to dictation in the total error rates for words or pseudowords (42% errors on words in both tasks; 100% vs. 97% errors on pseudowords).

In sum, at the time of Study 2 RCM still demonstrated marked difficulties in the written spelling of words and pseudowords, both in response to picture stimuli and in spelling to dictation. However, her pattern of errors changed substantially. Compared to Study 1, her rate of semantic errors in spelling had dramatically decreased, and her rate of errors that were both semantically and

TABLE V

Examples of RCM's Errors on Nonwords in Spelling to Dictation in Study 2

Stimulus	Response
hannee	*happened*
sarcle	*circled*
feen	*fiend*
wondoe	*wonder*
merber	*murmer*
sume	*assumption*
bruth	*brothered*
mushrame	*mustreresh*
snoy	*snoppy*

orthographically related to the target had increased. In addition, her accuracy in spelling pseudowords had significantly improved in terms of the percentage of correct phonological segments.

We have no data indicating that RCM's overall spelling accuracy significantly improved from Study 1 to Study 2. Unfortunately, we cannot directly test this possibility, since the same items were not presented on the two occasions. However, retrospective analysis of the data shows that 5/7 items that were included in both studies were incorrectly spelled in Study 1 and correctly spelled in Study 2. In Study 1, RCM made the following errors: grief → *sadness*; ant → *bugies*; violin → *guitar*; bribe → *bridge*; bottle → *bottom*. In Study 2, she spelled grief, ant, violin, bribe, and bottle correctly. We also examined words in Study 1 that contained the same final vowel-consonant segment, both phonologically and orthographically, to determine whether or not RCM improved in spelling words of the same probability of correct spelling by applying the most common phonology-to-orthography conversion (POC) "rules". We identified 10 such pairs (e.g., chief and thief). RCM's correct spelling of the same vowel-consonant segment improved from 0/10 to 8/10 ($\chi^2 = 13.3$; d.f. = 1; $p < .001$; Fisher's Exact: $p < .001$). For instance, she spelled "pair" as *two* in Study 1 and "chair" correctly in Study 2; she spelled "chain" as *chaimer* in Study 1 and "train" correctly in Study 2. Her improved accuracy on these pairs of words was not due to the higher frequency member of the pair being in Study 2. Of these 10 pairs, the mean frequency of the items in Study 1 was 32.2 (range = 1-81); and the mean frequency of the items in Study 2 was 47.6 (range 1-81; Kucera and Francis, 1980).

There is also some evidence that RCM's partially improved ability to spell sublexically (by POC mechanisms) did assist her spelling of some types of words. Her spelling of concrete words to dictation and in naming improved from 55% (28/51) to 74% (53/72) correct ($\chi^2 = 4.65$; d.f. = 1; $p < .03$; Fisher's Exact: $p < .04$) from Study 1 to Study 2. Although these lists included different items, improvement in spelling concrete words was also indicated by the fact that concrete words were spelled significantly more accurately than abstract words in Study 2, but not in Study 1. In the discussion section, we address why improved use of sublexical mechanisms might have aided spelling of concrete words more than abstract words.

More important than demonstrating improved accuracy of spelling, for our conclusions regarding RCM's spelling problems, is the fact that her error types changed. For example, she made errors of the the type "sale" spelled as *price* in Study 1, but not in Study 2; but made errors of the type "want" spelled as *wount* and "faith" spelled as *faithful* in Study 2. As discussed below, we believe these errors reflect an attempt to use re-emerging sublexical mechanisms for converting print to sound. Evidence that her phonology-to-orthography conversion mechanisms were re-emerging (although still impaired) comes from three analyses of the data reported here: (1) emergence of phonologically plausible errors in Study 2 (e.g., weave → *weve*); (2) her significantly improved percentage of correct phonologic segments in spelling to dictation; and (3) her significant improvement in spelling words with the same vowel-consonant segment (rime).

Discussion

The most striking aspect of RCM's performance is her production of semantic errors in written naming and writing to dictation, in the face of intact comprehension and intact oral naming. Her accurate performance in oral naming of the same words that elicited semantic errors in written production rules out the possibility that these semantic errors resulted from an impairment at the level of the semantic system. That is, it is difficult to believe that she consistently produced the correct oral names of these items unless she had intact semantic representations of these items[5]. Instead, we can account for these errors by proposing that RCM has damage to two components of the lexical system: (1) sublexical phonology-to-orthography correspondence mechanisms (and orthography-to-phonology correspondence mechanisms), and (2) access to representations in the orthographic output lexicon. To account for all aspects of RCM performance as a consequence of these two functional lesions, we must make the following assumptions. First, an intact semantic representation serves to activate a number of semantically related lexical representations in the orthographic output lexicon. When the target representation is unavailable due to an impairment at the level of the orthographic output lexicon (e.g., such that the target has a high threshold of activation or a low resting level of activation), the most activated lexical representation is selected for further processing[6]. One way in which a semantic representation might activate a number of semantically related lexical representations for output is schematically depicted in Figure 2. In this example, a semantic representation such as [bus] consists of a "distributed" representation of semantic features, including <for travel> <for multiple passengers> <has wheels> <has engine> <runs on gasoline> <made of metal> <for land> <moves on roads> <large, oblong>, and so on. Each of these features activates all of the lexical orthographic representations in the output lexicon to which it corresponds. To illustrate, <for travel> and <for multiple passengers> would activate bus, ship, train, van, ferry, airplane and so on. The features <moves on roads> would activate an overlapping set of lexical orthographic representations, including bus, van, car, bicycles, joggers, roadrunners and many more. In the absence of brain damage causing disruption at this level, the representation for bus would receive the greatest total activation from the entire set of features and would be selected for further processing. However, in the presence of damage at the level of orthographic lexical representations activated by the semantic system, the entry for bus might be unavailable, and so one of the competing lexical representations that is activated by many of the semantic

[5]We cannot rule out the possibility that RCM may have had a very mild impairment of semantics or access to phonological representations that caused her hesitations for word-finding in conversation. However, her normal performance on oral naming on our batteries (see Hillis, Benzing and Caramazza, 1995, for normative data) indicates that she did not have any notable impairment in accessing the semantic representation or the phonological representation of the items tested in these studies.

[6]Note that we are not claiming that the damage must necessarily involve orthographic lexical representations themselves. The damage could be to the pathway from the semantic system to the orthographic lexicon. However, without further specification of the nature of the mechanisms involved in lexical access in the orthographic lexicon the two alternatives are indistinguishable – in both cases the problem involves the normal activation and selection of lexical orthographic representations.

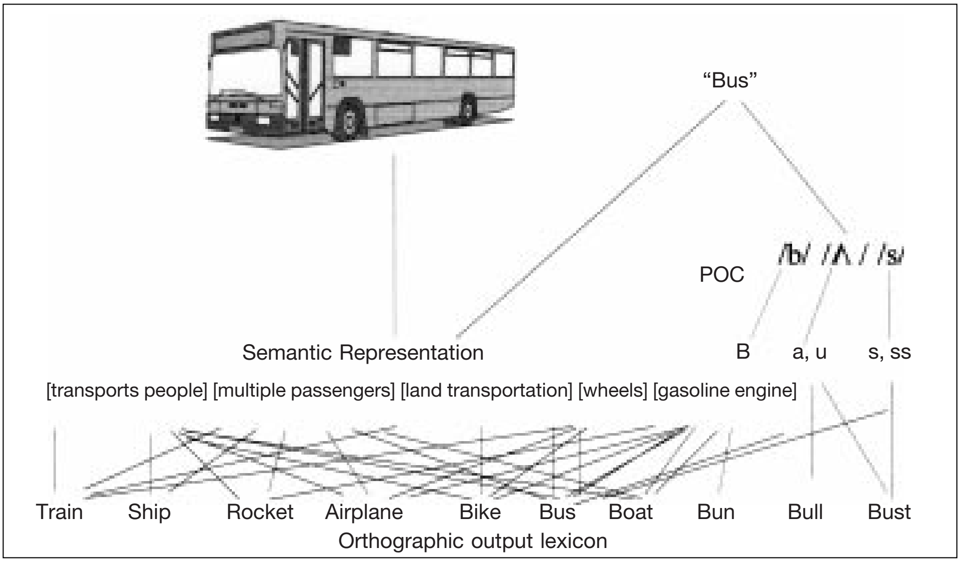

Fig. 2 – *A model of the representations and processes involved in written naming. POC refers to phonology-to-orthography conversion mechanisms.*

features might be selected instead. That is, whichever representation received activation to a level above its "threshold of activation" from the set of semantic features (or, alternatively, the most highly activated representation) would be selected for output (see, e.g., Caramazza and Hillis, 1990; Dell, 1986; Hillis, 1998, for such a proposal in the context of oral production)[7].

However, as noted in the Introduction, it is possible that lexical orthographic representations receive activation not only from the semantic system but also through input from phonology-to-orthography conversion mechanisms which convert a spoken stimulus into orthographic information. In the word production system schematically depicted in Figure 2, this information could be used to spell sublexically, which would result in a correct spelling or a plausible misspelling, such as *buss* for [bus]. Alternatively, information from phonology-to-orthography conversion mechanisms might also contribute to activation of the lexical orthographic representations that share phonemes with the target, such that the entries of bus, boat, bicycle, and truck (as well as bun, but, fuss, and so on) would receive some additional activation. At times, this additional activation would be enough to boost the activation level of the target above the activation levels of competing entries in the damaged lexical system. Thus, in the face of

[7]Note that this model of the naming does not include a lemma level of representation (Levelt, Schriefers, Vorberg et al., 1991). In fact, the production of semantic substitutions restricted to one modality of output (either speaking or writing) poses a serious challenge to models of lexical access that interpose a modality neutral lexical node (lemma) between the semantic system and the modality-specific lexical systems (see Caramazza, 1997, for detailed discussion). These models assume that the semantic system activates a series of modality-neutral lexical nodes from which the most highly activated node is selected for further processing. Once a lemma node is selected, activation flows to the next level of lexical representation where a modality-specific lexical node is selected for further processing. The activation of the latter lexical nodes does not involve semantic information. Thus, damage at the level of modality-specific lexical nodes (or to the connections to those nodes) does not predict the production of semantic errors. However, as we have seen, RCM's semantic errors arise from damage at the level of a modality-specific lexical

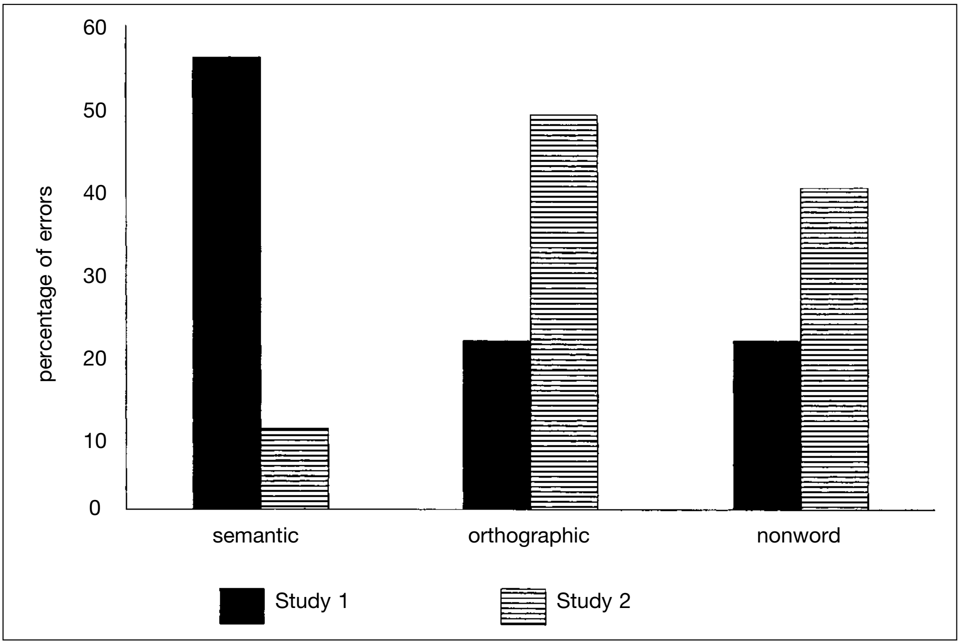

Fig. 3 – *Distribution of error types for Study 1* versus *Study 2.*

damage to the lexical orthographic system, we would expect spelling to dictation to be more accurate when phonology-to-orthography conversion mechanisms are intact than when they are damaged. Furthermore, this "summation" of information from the semantic system and the phonology-to-orthography conversion mechanisms would result in a reduction of purely semantic errors and an increase in errors that are both semantically and phonologically related to the stimulus. Consistent with this prediction, RCM's semantic errors in dictation occurred almost exclusively when she was unable to use sublexical phonology-to-orthography conversion mechanisms to spell nonwords (Study 1). By hypothesis, she was at that time unable to use these conversion mechanisms to facilitate the selection of lexical orthographic representations for output. When she improved in using phonology-to-orthography conversion mechanisms (as indicated by the number of nearly correct responses in spelling nonwords, as well as the production of phonologically plausible errors in Study 2), she made many more errors that were both semantically and phonologically/orthographically related to the stimulus (e.g., "bus" → *boat*; "loyal" → *loyalty*). There was also a corresponding decline in the production of purely semantic errors, as illustrated in Figure 3.

The summation hypothesis may also account for RCM's orthographically/ phonologically similar, unrelated word errors in written picture naming and dictation (e.g., "myth" → *method*) when she improved in spelling nonwords (Study 2). In the writing system schematically depicted in Figure 2, we can account for RCM's phonologically/orthographically similar word errors by proposing that they arose as a consequence of her improved (but still subnormal)

phonology-to-orthography conversion mechanisms. These partially functioning mechanisms activate orthographic representations in the lexicon. In some cases, the activation from phonology-to-orthography conversion mechanisms might be stronger or faster than activation from the intact semantic representation, so that the phonologically related lexical representation would be selected instead of a semantically related representation (see Saffran, 1985, for a similar argument concerning visually similar word errors in reading)[8].

One might also predict that improved phonology-to-orthography conversion should eliminate semantic errors in written naming, since the subject should be able to retrieve the correct verbal name and "convert" it to an oral name through these sublexical procedures. However, this prediction rests on the hypothesis that phonological mediation is compulsory in written naming; i.e., that subjects necessarily access the phonological representation, which then serves to access the orthographic representation. But we have laid out an alternative to the hypothesis of phonological mediation – that lexical orthographic representations can be accessed directly from the semantic representation. On this account, RCM would not access the lexical phonological representation prior to accessing the orthographic representation, so that neither her ability to name aloud nor her improved sublexical sublexical conversion mechanisms would influence her written naming. Note that we are not refuting that phonological mediation can take place – indeed, it may be customary when sublexical mechanisms are entirely normal. Rather, we are claiming that phonological mediation is not *necessary* for written naming.

A final aspect of RCM's performance deserves discussion. Her spelling to dictation was significantly affected by the parameters of concreteness and frequency, and a trend toward a word class effect. She was more accurate in spelling concrete words than abstract words. This commonly reported concreteness effect in cases of "deep dysgraphia," as well as "deep dyslexia," has been cited as evidence that the errors come from a damaged semantic system, since concreteness should only have an effect on representations at this level (Shallice, 1988; see also papers in Coltheart et al., 1980). However, a concreteness effect might also emerge as a consequence of the way in which lexical representations are activated by the semantic system. That is, it may be that concrete words have semantic features that correspond to fewer lexical representations, such that there are fewer competing representations activated in response to each stimulus. For example, the semantic representation of a concrete concept like [bus] shares a majority of its semantic features with only a few items (van, train, subway/underground, trolley), whereas

[8]Another explanation for the presence of orthographically/phonologically similar, unrelated word errors is to assume that they arise in the short term maintenance of the lexical orthographic representation (in the "graphemic buffer"). This explanation requires that one consequence of RCM's damage at the level of lexical orthographic representations is weaker activation of the segmental content of lexical representations in the graphemic buffer. A possible further consequence is that a "repair" attempt based on partial output might on occasion lead RCM astray. Sometimes this results in a word response, sometimes in a nonword. Consider for example the response "frequent" → *friength*. Suppose that after mistakenly writing <i> insread of <e>, RCM were induced toward a repair leading to *friend*. Fowever, another error <g> for <d>, in turn, led to a repair based on <eng>, as in strength, with the consequence that she finally produced *friength*. Now, this is purely speculative and we have no way of testing this intuition. Nonetheless, it may not be far from the truth. Thus, consider "member" → *memory*, "strange" → *instrance* (instance?, entrance?), "child" → *childress* (children → address?); "belief" → *believen* (even?). This account could explain both RCM's nonword spelling errors and her frequent pseudo-morphological errors (e.g., "jury" → *jured*; "strong" → *strength*; "digit" → *digity*).

the semantic features of an abstract word, say [faith], shares a majority of its semantic features with many other abstract concepts (belief, credence, creed, tenet, confidence, denomination, hope, reliance, religion, trust, certainty, conviction, doctrine, dogma, persuasion, sect), at least in certain contexts. Therefore, an impairment in accessing the target orthographic representation of the word faith might result in activation of a large number of competing lexical representations, some of which might have higher activation than the target response. This hypothesis might explain why improved phonology-to-orthography conversion assisted RCM's spelling of concrete words more than abstract words (which have more competitors, and therefore more likely to have phonologically similar competitors). Similarly, the trend toward more difficulty with verbs relative to nouns may result from the greater overlap in semantic features of verbs relative to nouns. To illustrate, the transitive verb [run] shares a majority of its semantic features with many other verbs, including: jog, dash, sprint, flee, bolt, gallop, go, hurry, hustle, race, rush, and trot (and, of course, other meanings of <run> overlap with many other concepts). As argued by others, the effect of word frequency on the accuracy of written output can be explained by assuming that high frequency words have lexical orthographic representations that are more "available" (have a higher "resting state of activation" or a lower "threshold for selection") compared to low frequency words. Therefore, when a number of lexical representations are partially activated by the semantic representation, the one with the highest word frequency would have the highest likelihood of being selected.

Leaving aside the details of the explanations we have offered for various aspects of RCM's performance (e.g., the exact way in which pseudo-morphological errors arise in RCM, discussed in footnote 8), which may be wrong in detail, there are several implications that follow from her performance for models of normal lexical access and models of naming, reading and writing disorders, which we outline below.

The Causes of Naming Errors

In the Introduction we noted that various researchers have argued that semantic errors in naming can arise from damage to different components of the naming process. One way to establish the locus of impairment in a cognitive system is to assess and compare performance for tasks that share some components of processing but not others. For example, written and spoken naming share object recognition and semantic processes but not lexical output processes; writing involves accessing lexical orthographic representations, whereas speaking involves accessing lexical phonological representations. The selective impairment of one of the tasks can be taken as evidence that a component of processing not shared by the two tasks is most likely responsible for the observed deficit. In the case of RCM, the fact that she made naming errors only in writing tasks and not in comprehension or oral production tasks can be taken to indicate that the cause of her naming deficit cannot be damage to either the object recognition system or the semantic system – two components of processing that are shared by the oral and written naming tasks and that, if damaged, would have resulted in naming deficits for both tasks. Furthermore,

since the predominant error type produced by RCM in written naming consisted of semantic substitutions, we can rule out a primary impairment to post-lexical processing components as the cause of the deficit. This leaves damage to the orthographic lexicon (or to the connections from the semantic system to the orthographic lexicon) as the only plausible source of RCM's semantic errors in writing. As noted earlier, we must also propose concurrent damage to sublexical mechanisms for converting phonology to orthography to account for other types of errors and other aspects of her performance.

Other patients have been reported who made semantic errors exclusively in one modality of output (either in writing or in speaking) and who showed intact performance in comprehension tasks (Caramazza and Hillis, 1990, 1991; Hillis and Caramazza, 1995a, 1995c; Shelton and Weinrich, 1997). In each case, the locus of impairment responsible for the semantic errors in naming was found to be damage to a modality-specific lexicon. These cases contrast with patients who make semantic errors in spoken and written naming and who make semantic errors in comprehension tasks. For the latter patients, the most likely locus of damage is the semantic system. In other words, the production of semantic errors in naming can result either from damage to the semantic system or damage to modality-specific lexical form systems.

The conclusion we have reached on the basis of RCM's performance and that of similar and contrasting cases is highly problematic for a model of naming deficits recently proposed by Dell, Schwartz, Martin et al. (1997; see also Schwartz, Saffran, Bloch et al., 1994). These authors argued that the different mixes of semantic and other errors in naming arise from undifferentiated damage to all levels of the lexical production system – from the semantic component to the segmental level. They called this assumption regarding the source of naming errors the "globality" assumption. In support of their claim they report a simulation study that, they argue, shows that the different mixtures of naming errors (i.e., the proportions of semantic, lexical, and segmental errors) produced by a group of aphasic patients could be simulated by different degrees of global damage to an interactive network model of naming. Leaving aside whether Dell et al. (1997) and Schwartz et al. (1994) have actually demonstrated that their model can account for the performance of the patients included in their study (for a critical assessment see Ruml and Caramazza, in press), it is quite clear that the performance of RCM and similar cases undermines the globality assumption. RCM's naming performance cannot be ascribed to a lesion involving all components of the word production system (as required by the globality assumption), because such a global impairment would result in errors also in the oral naming task. This expectation is based on the assumption that written and oral naming engage a common semantic component. Unless Dell et al. (1997) and Schwartz et al. (1994) are willing to reject the latter assumption they must reject their globality assumption of naming deficits. In other words, naming deficits can have different loci of impairment contrary to the globality assumption.

A methodological implication that follows from this analysis may be worth stressing: Attempts to explain performance of patients by focusing on a single task (as was done by Dell et al., 1994) can lead to misleading conclusions. In order to be able to determine the locus of damage to a cognitive system it is

unlikely that we would be able to reach the right conclusion by considering performance on a single task. We have seen that in order to establish the locus of impairment in RCM we have had to consider naming performance in tasks involving different modalities of output as well as performance in comprehension tasks. Furthermore, since the incidence of semantic errors may depend on the integrity of sublexical phonology-to-orthography conversion processes, we have also had to consider performance in processing pseudowords. It is only through the analysis of the (thoeretically-motivated) overall pattern of performance across the various tasks performed by RCM that we have been able to identify the plausible loci of impairment for her naming deficit. Had we considered only her written naming performance we would not have been able to unambiguously determine the source of errors. Similarly, Dell et al.'s focus on the single task of naming has led them to a conclusion about the causes of naming impairments that is empirically untenable, since certain mixtures of naming errors, such as the one obtained for RCM, cannot be explained by the globality assumption.

The Causes of "Deep Dysgraphia"

RCM's spelling deficit can be classified as deep dysgraphia. She made semantic and lexical substitution errors in writing to dictation; she could not spell nonwords; and she showed a concreteness effect and a marginal trend for a word class effect (Bub and Kertesz, 1982a). However, the cause of her semantic errors is different from that of some other deep dysgraphic patients (e.g., Newcombe and Marshall, 1980; Nolan and Caramazza, 1983), since RCM does not have a semantic deficit. In her case, the combination of features that define the disorder seems to arise from the co-occurrence of impairments at two levels of processing in writing: access to representations in the orthographic output lexicon and sublexical procedures for converting phonology to orthography. The co-occurrence of these two deficits in some stroke patients may be due to the anatomical proximity of mechanisms that increases the chances of their being in the same vascular territory (and subject to damage by a single stroke). In this sense, "deep dysgraphia" might be considered a clinical syndrome, if it correlates with a particular area of the brain. Indeed, if the explicit aim of examination of aphasia is "the diagnosis of presence and type of aphasic syndromes, leading to inferences concerning cerebral localization..." (Goodglass and Kaplan, 1972, p. 1), then the identification of deep dysgraphia or other forms of pure agraphia may prove worthwhile. For example, in classical aphasiology, RCM would simply be categorized as "pure agraphic", and predicted to have damage to the angular gyrus or "to the foot of the second frontal convolution, [where] it may represent a way station for recoding the output of Broca's area and/or the angular gyrus association areas into the form where it can activate the effectors for writing movements" (p. 77, Goodglass and Kaplan, 1972, attributed to Exner, 1881). It is possible that damage to different cognitive mechanisms in the writing system are associated with one or the other of these areas. As shown in Figure 1, RCM likely has a lesion in the second frontal convolution, but she does not have an isolated lesion to this area as

expected in cases of pure agraphia (Goodglass and Kaplan, 1972, p. 79): she also has damage to Broca's area without the clinical syndrome of "Broca's aphasia." But irrespective of the correlation between the clinical syndrome and the vascular distribution of infarct, we would argue that "deep dysgraphia" is not a theoretically coherent syndrome, in the sense that it would require a single computational or neuroanatomical account. First, we have proposed that the collection of features that constitute deep dysgraphia can arise from different levels of impairment in processing (e.g, the semantic system or the output lexicon, in addition to phonology-to-orthography conversion mechanisms). Furthermore, the features can be expected to dissociate when there is damage at only one level of processing. Detailed analysis of individual patterns of performance can provide evidence for proposing damage to specific components of the cognitive system underlying writing. In turn, such proposals serve to articulate hypotheses about the structure of the mental representations and processes that constitute this cognitive system. In the case of RCM, the pattern of errors across tasks with different input and output modalities provides evidence for the hypothesis that semantic features activate in parallel all of the orthographic lexical representations to which they correspond. Additionally, the change in her pattern of errors from Study 1 to Study 2 provides evidence for the interaction of sublexical phonology-orthography conversion mechanisms and lexical representations for written output.

Conclusion

We have reported the performance of a patient with damage to the left frontal lobe who presents with a striking dissociation between speaking and writing. RCM produces semantic errors in written but not in oral naming. Furthermore, she shows intact comprehension in various lexical processing tasks. In writing to dictation she makes semantic errors and orthographically/phonologically similar word and nonword errors. The incidence of the latter errors increased as her ability to use sublexical phonology-to-orthography conversion processes improved. We interpreted the latter result as indicating that sublexical and lexical processes interact in selecting a lexical orthographic representation for written output.

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